



Blackjack Cards Analysis – January 2021

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **January 01, 2021 to January 31, 2021** as recorded by the respective game servers. The game logs were for blackjack games using 8 decks. iTech Labs has analysed the blackjack cards for statistical randomness. The results of the analysis are given below.

For details on the gaming sites serviced by the Entain Plc game servers and used in this audit refer to the [List](#).

1. Blackjack hand value

Blackjack hand value analysis involved creating subsets of data and conducting Chi-square tests on each subset. Opening hands are the value of the first two cards dealt. Final hand value is the hand value at the end of the game. Dealer final hand value is based on the fixed rules of the game. Player final hand value is dependent on player strategy choice, so has no theoretical basis for comparison.

The null hypothesis for the chi-square test is that the observed frequencies of each type of hand matches the theoretical values for a deck that has been shuffled using a perfect random number generator. The p-values observed in these multiple tests are expected to follow a uniform distribution for the range 0.0 to 1.0.

The analysis performs a KS Test (Kolmogorov-Smirnov test) for uniform distribution on the observed p-values, and the combined p-value result of this test is taken as the final result of the blackjack opening hand value statistics tests.

1.1 Player's opening score (from first two cards):

Test No.	DOF	ChiSqr	P-Value
1	17	14.96	0.59825
2	17	14.30	0.64595
3	17	16.42	0.49460
4	17	20.82	0.23467
5	17	8.88	0.94396
6	17	7.72	0.97223
7	17	10.99	0.85704
8	17	21.45	0.20694
9	17	18.72	0.34493
10	17	10.07	0.90055
11	17	13.11	0.72892
12	17	21.11	0.22143
13	17	19.82	0.28355
14	17	19.32	0.31041
15	17	16.74	0.47236
16	17	18.35	0.36715
17	17	14.77	0.61199
18	17	11.94	0.80383
19	17	14.90	0.60293
20	17	20.96	0.22813
21	17	19.01	0.32802
22	17	10.28	0.89155
23	17	12.98	0.73723

24	17	15.15	0.58475
25	17	26.19	0.07102
26	17	31.44	0.01765
27	17	15.21	0.58055
28	17	20.50	0.24954
29	17	15.15	0.58501
30	17	15.00	0.59553
31	17	10.17	0.89641
32	17	11.57	0.82534
33	17	15.26	0.57678
34	17	15.13	0.58608
35	17	24.10	0.11670
36	17	15.13	0.58609
37	17	10.01	0.90332
38	17	8.82	0.94583
39	17	12.85	0.74619
40	17	8.50	0.95478
41	17	13.32	0.71479
42	17	12.93	0.74072
43	17	15.77	0.54015
44	17	14.30	0.64549
45	17	14.13	0.65757
46	17	16.34	0.49967
47	17	25.54	0.08334
48	17	14.88	0.60403
49	17	9.31	0.93009
50	17	13.54	0.69963
51	17	16.23	0.50791
52	17	9.81	0.91124
53	17	13.15	0.72626
54	17	15.62	0.55116
55	17	10.17	0.89652
56	17	17.79	0.40214
57	17	30.21	0.02485
58	17	11.42	0.83378
59	17	33.88	0.00871
60	17	12.76	0.75201
61	17	20.26	0.26124
62	17	12.98	0.73752
63	17	14.73	0.61516
64	17	19.93	0.27780
65	17	14.11	0.65905
66	17	10.41	0.88571
67	17	13.85	0.67791
68	17	18.48	0.35943
69	17	11.73	0.81617
70	17	14.60	0.62420
71	17	16.74	0.47239
72	17	23.68	0.12829
73	17	22.34	0.17216
74	17	21.76	0.19409
75	17	25.23	0.08959
76	17	26.22	0.07062
77	17	17.81	0.40092
78	17	8.42	0.95668

79	17	14.21	0.65235
80	17	18.60	0.35172
81	17	11.81	0.81175
82	17	14.87	0.60459
83	17	26.19	0.07100
84	17	35.61	0.00517
85	17	21.12	0.22105
86	17	18.37	0.36578
87	17	27.58	0.05014
88	17	17.89	0.39572
89	17	22.77	0.15681
90	17	17.68	0.40955
91	17	35.66	0.00510
92	17	14.44	0.63589
93	17	13.06	0.73225
94	17	11.76	0.81420
95	17	30.75	0.02142
96	17	20.62	0.24364
97	17	16.42	0.49413
98	17	12.82	0.74794
99	17	19.86	0.28133
100	17	18.04	0.38633
Combined P-value for all tests (Using KS method)			0.29154

Notes:

- 1) The P-values are observed probabilities from the Chi-Square tests. The last row shows the result of the KS Test performed on the p-values for all Chi-Square tests, where there are sufficient data.

1.2 Dealer's opening score (from first two cards):

Test No.	DOF	ChiSqr	P-Value
1	17	13.58	0.69666
2	17	12.07	0.79583
3	17	21.18	0.21813
4	17	16.54	0.48569
5	17	12.80	0.74933
6	17	8.87	0.94438
7	17	14.11	0.65916
8	17	19.69	0.29024
9	17	14.16	0.65587
10	17	17.95	0.39220
11	17	28.96	0.03487
12	17	9.89	0.90819
13	17	7.90	0.96866
14	17	18.59	0.35247
15	17	30.70	0.02169
16	17	17.58	0.41604
17	17	16.46	0.49124
18	17	24.16	0.11522
19	17	18.01	0.38796
20	17	19.39	0.30672
21	17	15.00	0.59551
22	17	20.63	0.24344
23	17	15.34	0.57117

24	17	22.62	0.16206
25	17	9.35	0.92857
26	17	17.07	0.44987
27	17	28.22	0.04245
28	17	12.68	0.75736
29	17	14.30	0.64556
30	17	13.91	0.67344
31	17	14.99	0.59650
32	17	16.91	0.46053
33	17	25.46	0.08478
34	17	11.57	0.82551
35	17	8.88	0.94392
36	17	15.46	0.56267
37	17	16.16	0.51234
38	17	15.30	0.57355
39	17	9.28	0.93096
40	17	19.48	0.30166
41	17	20.08	0.27031
42	17	18.61	0.35109
43	17	16.76	0.47055
44	17	16.15	0.51318
45	17	22.75	0.15767
46	17	16.41	0.49484
47	17	24.99	0.09484
48	17	13.46	0.70517
49	17	23.64	0.12941
50	17	13.47	0.70422
51	17	7.66	0.97326
52	17	11.90	0.80623
53	17	12.64	0.76015
54	17	14.28	0.64705
55	17	16.15	0.51341
56	17	15.28	0.57514
57	17	9.13	0.93616
58	17	15.12	0.58692
59	17	15.93	0.52861
60	17	17.24	0.43822
61	17	22.91	0.15231
62	17	18.47	0.35969
63	17	14.34	0.64301
64	17	25.43	0.08539
65	17	14.88	0.60437
66	17	5.19	0.99717
67	17	9.56	0.92101
68	17	18.97	0.33034
69	17	17.40	0.42791
70	17	23.73	0.12701
71	17	30.03	0.02612
72	17	22.90	0.15254
73	17	21.35	0.21101
74	17	43.70	0.00038
75	17	12.03	0.79835
76	17	11.76	0.81418
77	17	18.59	0.35250
78	17	11.61	0.82336

79	17	32.43	0.01329
80	17	23.67	0.12873
81	17	20.55	0.24712
82	17	18.95	0.33170
83	17	14.62	0.62296
84	17	16.02	0.52218
85	17	28.09	0.04388
86	17	25.12	0.09198
87	17	14.49	0.63221
88	17	15.09	0.58920
89	17	14.13	0.65759
90	17	22.57	0.16381
91	17	20.16	0.26631
92	17	17.20	0.44073
93	17	15.28	0.57547
94	17	10.88	0.86286
95	17	19.71	0.28940
96	17	18.32	0.36906
97	17	18.83	0.33846
98	17	10.21	0.89463
99	17	13.57	0.69718
100	17	13.77	0.68342
Combined P-value for all tests (Using KS method)			0.61348

Notes:

- 1) The P-values are observed probabilities from the Chi-Square tests. The last row shows the result of the KS Test performed on the p-values for all Chi-Square tests, where there are sufficient data.

1.3 Dealer's final score (total of all cards for hands with 3 or more cards):

Test No.	DOF	ChiSqr	P-Value
1	50	40.31	0.83435
2	50	55.61	0.27179
3	50	36.30	0.92677
4	50	49.89	0.47798
5	50	52.22	0.38774
6	50	49.71	0.48516
7	50	51.38	0.41934
8	50	46.91	0.59796
9	50	42.57	0.76295
10	50	64.09	0.08688
11	50	42.80	0.75507
12	50	65.87	0.06558
13	50	59.07	0.17793
14	50	52.76	0.36791
15	50	33.08	0.96881
16	50	52.88	0.36338
17	50	48.26	0.54359
18	50	56.65	0.24085
19	50	47.16	0.58822
20	50	46.74	0.60514
21	50	60.34	0.15014
22	50	44.87	0.67874
23	50	68.38	0.04303

24	50	56.39	0.24830
25	50	38.47	0.88264
26	50	44.30	0.70062
27	50	51.15	0.42837
28	50	52.89	0.36330
29	50	64.92	0.07628
30	50	50.34	0.45986
31	50	51.08	0.43093
32	50	50.19	0.46605
33	50	47.67	0.56738
34	50	42.79	0.75536
35	50	47.83	0.56100
36	50	68.41	0.04284
37	50	74.04	0.01521
38	50	57.73	0.21115
39	50	44.60	0.68901
40	50	40.84	0.81900
41	50	36.84	0.91688
42	50	55.01	0.29066
43	50	75.88	0.01057
44	50	70.50	0.02957
45	50	50.88	0.43880
46	50	45.07	0.67105
47	50	62.49	0.11059
48	50	38.48	0.88231
49	50	45.88	0.63932
50	50	45.07	0.67105
51	50	58.90	0.18201
52	50	48.46	0.53520
53	50	49.98	0.47419
54	50	50.37	0.45871
55	50	35.74	0.93596
56	50	66.36	0.06056
57	50	45.07	0.67118
58	50	45.27	0.66315
59	50	29.62	0.99031
60	50	52.11	0.39172
61	50	62.59	0.10894
62	50	48.88	0.51828
63	50	47.83	0.56108
64	50	45.65	0.64862
65	50	43.25	0.73901
66	50	57.47	0.21807
67	50	49.61	0.48912
68	50	37.48	0.90433
69	50	76.91	0.00858
70	50	50.17	0.46659
71	50	54.30	0.31401
72	50	56.24	0.25280
73	50	53.08	0.35634
74	50	54.83	0.29663
75	50	48.32	0.54120
76	50	47.95	0.55583
77	50	44.61	0.68891
78	50	39.04	0.86872

79	50	40.49	0.82929
80	50	46.68	0.60740
81	50	52.80	0.36638
82	50	49.60	0.48944
83	50	48.75	0.52359
84	50	40.82	0.81942
85	50	65.86	0.06566
86	50	31.78	0.97919
87	50	53.37	0.34592
88	50	48.35	0.53975
89	50	68.75	0.04040
90	50	50.83	0.44065
91	50	38.25	0.88769
92	50	48.08	0.55091
93	50	54.45	0.30887
94	50	53.76	0.33224
95	50	54.95	0.29262
96	50	43.80	0.71914
97	50	36.51	0.92299
98	50	61.94	0.11981
99	50	50.09	0.46994
100	50	37.06	0.91274
Combined P-value for all tests			0.67901

Notes:

- 1) The P-values are observed probabilities from the Chi-Square tests. The last row shows the result of the KS Test performed on the p-values for all Chi-Square tests, where there are sufficient data.

2. Blackjack rank statistics

The blackjack rank analysis aims to establish that the rank of the cards to player and dealer was equally distributed in one of the 13 possible ranks (2, 3, 4, 5, 6, 7, 8, 9, 10, J, Q, K, A).

The blackjack rank analysis involved creating subsets of data and conducting Chi-square tests on each subset. The analysis performs a KS Test (Kolmogorov-Smirnov test) for uniform distribution on the observed p-values, and the combined p-value result of this test is taken as the final result of the Ranks statistics tests.

2.1 Blackjack rank statistics for all player cards:

Test No.	DOF	ChiSqr	P-Value
1	12	7.91	0.79250
2	12	14.07	0.29644
3	12	7.92	0.79138
4	12	13.20	0.35444
5	12	7.71	0.80746
6	12	6.20	0.90547
7	12	11.76	0.46476
8	12	8.56	0.73991
9	12	10.78	0.54790
10	12	7.86	0.79628
11	12	15.94	0.19377
12	12	15.60	0.21020
13	12	6.89	0.86454
14	12	3.80	0.98683
15	12	21.76	0.04030

16	12	14.51	0.26921
17	12	16.12	0.18588
18	12	17.99	0.11608
19	12	12.46	0.40963
20	12	16.21	0.18165
21	12	14.51	0.26938
22	12	7.44	0.82701
23	12	8.40	0.75274
24	12	13.89	0.30792
25	12	5.24	0.94931
26	12	8.45	0.74920
27	12	8.64	0.73318
28	12	6.01	0.91572
29	12	16.90	0.15358
30	12	18.12	0.11210
31	12	9.99	0.61642
32	12	19.64	0.07414
33	12	10.05	0.61185
34	12	17.12	0.14528
35	12	3.61	0.98950
36	12	16.29	0.17811
37	12	14.15	0.29142
38	12	6.82	0.86959
39	12	6.90	0.86393
40	12	12.47	0.40851
41	12	15.19	0.23096
42	12	8.85	0.71540
43	12	9.76	0.63671
44	12	3.48	0.99105
45	12	11.60	0.47797
46	12	4.67	0.96803
47	12	19.35	0.08038
48	12	9.42	0.66668
49	12	21.11	0.04880
50	12	8.52	0.74345
51	12	7.64	0.81246
52	12	22.45	0.03281
53	12	11.07	0.52283
54	12	13.26	0.35077
55	12	23.10	0.02692
56	12	19.01	0.08837
57	12	12.95	0.37280
58	12	3.79	0.98692
59	12	7.46	0.82579
60	12	13.98	0.30212
61	12	20.53	0.05770
62	12	12.23	0.42733
63	12	17.69	0.12532
64	12	19.30	0.08165
65	12	7.34	0.83452
66	12	8.62	0.73527
67	12	12.81	0.38315
68	12	3.26	0.99338
69	12	11.44	0.49204
70	12	10.28	0.59157

71	12	20.14	0.06444
72	12	6.90	0.86443
73	12	12.39	0.41514
74	12	12.40	0.41433
75	12	9.12	0.69277
76	12	10.62	0.56206
77	12	6.93	0.86241
78	12	5.61	0.93440
79	12	9.77	0.63580
80	12	12.32	0.42060
81	12	12.98	0.37015
82	12	12.41	0.41352
83	12	16.00	0.19132
84	12	10.12	0.60524
85	12	6.87	0.86594
86	12	9.16	0.68964
87	12	14.14	0.29207
88	12	10.24	0.59498
89	12	21.03	0.04999
90	12	13.00	0.36920
91	12	8.90	0.71187
92	12	5.09	0.95486
93	12	9.58	0.65309
94	12	6.82	0.86943
95	12	13.36	0.34348
96	12	11.05	0.52483
97	12	11.92	0.45180
98	12	21.59	0.04234
99	12	14.99	0.24216
100	12	9.76	0.63668
Combined P-value for all tests (Using KS method)			0.93361

Notes:

- 1) The P-values are observed probabilities from the Chi-Square tests. The last row shows the result of the KS Test performed on the p-values for all Chi-Square tests, where there are sufficient data.

2.2 Blackjack rank statistics for all dealer cards:

Test No.	DOF	ChiSqr	P-Value
1	12	13.49	0.33459
2	12	13.45	0.33692
3	12	12.26	0.42487
4	12	18.87	0.09181
5	12	8.57	0.73948
6	12	10.62	0.56139
7	12	9.88	0.62649
8	12	12.64	0.39574
9	12	5.65	0.93287
10	12	16.37	0.17504
11	12	13.65	0.32361
12	12	10.08	0.60912
13	12	18.01	0.11539
14	12	15.58	0.21144
15	12	7.64	0.81289

16	12	9.92	0.62315
17	12	7.06	0.85376
18	12	5.92	0.92026
19	12	5.91	0.92075
20	12	18.70	0.09598
21	12	16.17	0.18340
22	12	21.77	0.04016
23	12	14.18	0.28936
24	12	16.53	0.16823
25	12	12.31	0.42080
26	12	9.15	0.69024
27	12	14.18	0.28961
28	12	8.15	0.77314
29	12	5.49	0.93950
30	12	9.70	0.64191
31	12	6.94	0.86142
32	12	7.23	0.84191
33	12	14.19	0.28849
34	12	9.60	0.65118
35	12	7.70	0.80811
36	12	16.32	0.17684
37	12	9.69	0.64331
38	12	11.96	0.44874
39	12	7.74	0.80480
40	12	17.56	0.12958
41	12	9.86	0.62842
42	12	11.03	0.52618
43	12	12.48	0.40809
44	12	14.94	0.24451
45	12	22.18	0.03557
46	12	9.70	0.64204
47	12	9.75	0.63830
48	12	12.44	0.41131
49	12	11.16	0.51491
50	12	6.73	0.87497
51	12	11.64	0.47504
52	12	4.34	0.97660
53	12	11.83	0.45921
54	12	5.28	0.94780
55	12	10.04	0.61240
56	12	20.32	0.06134
57	12	3.84	0.98613
58	12	7.62	0.81430
59	12	9.49	0.66053
60	12	16.63	0.16391
61	12	20.37	0.06043
62	12	7.55	0.81909
63	12	11.18	0.51396
64	12	10.36	0.58441
65	12	7.68	0.80932
66	12	7.55	0.81895
67	12	16.63	0.16414
68	12	16.78	0.15798
69	12	10.85	0.54179
70	12	19.33	0.08083

71	12	7.87	0.79524
72	12	13.00	0.36938
73	12	10.85	0.54163
74	12	17.87	0.11963
75	12	7.44	0.82705
76	12	13.74	0.31737
77	12	14.49	0.27072
78	12	13.63	0.32468
79	12	11.49	0.48768
80	12	17.25	0.14030
81	12	11.37	0.49732
82	12	15.58	0.21140
83	12	19.85	0.07001
84	12	18.32	0.10632
85	12	10.43	0.57873
86	12	5.48	0.94018
87	12	9.15	0.69046
88	12	18.93	0.09017
89	12	11.01	0.52838
90	12	14.68	0.25921
91	12	6.43	0.89307
92	12	6.30	0.90009
93	12	11.27	0.50578
94	12	10.44	0.57711
95	12	12.71	0.39010
96	12	12.87	0.37850
97	12	6.46	0.89093
98	12	17.18	0.14284
99	12	14.29	0.28236
100	12	10.19	0.59969
Combined P-value for all tests (Using KS method)			0.96319

Notes:

- 1) The P-values are observed probabilities from the Chi-Square tests. The last row shows the result of the KS Test performed on the p-values for all Chi-Square tests, where there are sufficient data.

4. Summary of the analysis of blackjack tests

The Blackjack cards analysis completes by combining the result of the KS Test performed in the two types of analysis (Hand Values and Ranks) for using the Holm's method and producing a single Combined P -value.

The combined p-value produced using the Holm's method is used as indication for statistical randomness.

Combination of p-values using Holm's Method		
Test	P-Value	P-Adjusted
Opening Score (Player)	0.29154	1.00000
Opening Score (Dealer)	0.61348	1.00000
Dealer's Final Score	0.67901	1.00000
Player Cards Rank	0.93361	1.00000
Dealer Cards Rank	0.96319	1.00000
Combined P-Value using Holm's Method		1.00000

Notes:

- 1) The combined p-value of all statistical tests using Holm's Method conducted for blackjack is greater than the minimum value of 0.05 which indicates that the randomness of the observed data falls within 95% confidence limits.

The final outcome of the analysis of blackjack indicates that the RNG is working correctly.

5. Conclusion

Analysis of actual data from game logs for 'player opening score', 'dealer opening score', 'dealer final score', 'player card rank' and 'dealer card rank' indicated statistical randomness. The results were satisfactory for 8 deck blackjack.

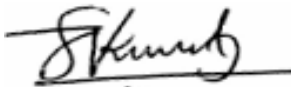
We conclude that the Random Number Generator (RNG) is working correctly.

iTech Labs has done limited sanity checks to verify the integrity of the game logs. iTech Labs also maintains a copy of the game logs for verification purposes. There were a large enough number of game records to give the calculations sufficient statistical power.

The scope of the review did not include reviews of financial controls or casino operations. We believe that the probabilities were calculated correctly from the game logs.

Please click here to see the [Original](#) report.

Signed:



Kiren Sreekumar
Principal Consultant
iTech Labs Australia
Date: 04 May, 2021

Signed:



Gyulserian Hyusseini
Senior Consultant
iTech Labs Australia
Date: 04 May, 2021

Disclaimer.

While it is not possible to test all possible scenarios in a laboratory environment, iTech Labs has conducted a level of testing appropriate for a component test of this type.